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Section XI

Uses of Nonmetallic Chemically Resistant Materials in Waste Handling

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Uses of Nonmetallic Chemically Resistant Materials in Waste Handling

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Industrial wastes–acids, alkalies, salts, bleaches, all sorts of corrosive and noncorrosive waste products–have been with us since the earliest days of man. Leftovers from savages' community meals and from battlefield dead, have been handled by animals and insects. What was not consumed was "biodegraded" to fertilize plant growth. As man became "civilized" and learned to make things, the wastes remaining from the processes he developed were no longer consumable by animal or insect, and most were not biodegradable either. Trash was simply dumped in pits, and liquid wastes poured into holes in the ground from which it ran off, or filtered into subsurface streams. (Perhaps this is a reflection on what civilization means.) As population expanded and man became less migratory, tending to settle in specific areas, various efforts were made to move the trash and liquid wastes away from towns and villages. Solid wastes were hauled off, then dumped. And ages ago someone thought of piping liquid wastes away from their sources to a collecting spot.

PIPING

Small diameter baked clay piping, formed and fired in the same way that clay pottery and tile or brick were made, has been available from the earliest times. Larger diameter vitrified clay pipe which must date from revolutionary, perhaps colonial, days has been unearthed in the United States. Sections of pipe, made with bell and spigot ends, three to six feet long were fitted together, caulked with "oakum" (treated wool waste) and this packing backed with hot

poured tar or asphalt. This was the usual method of constructing sanitary and industrial sewer lines well into the third decade of this century.

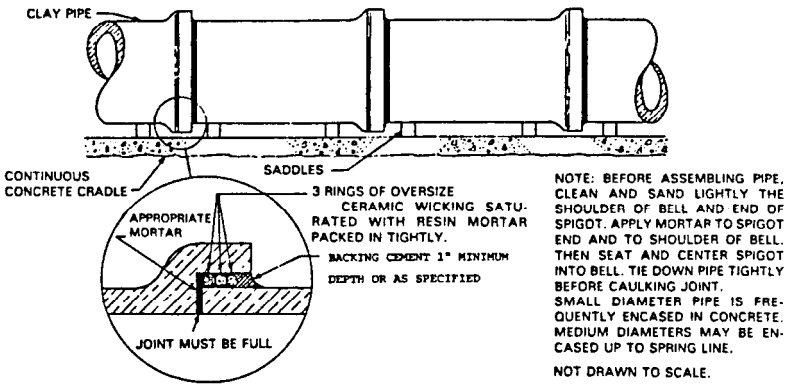
Human and animal wastes are biodegradable and are still the main sources of fertilizer in the largest areas of the world. Therefore, it was reasoned, joints in pipe that leaked a little (exfiltration) would not be harmful. On the other hand, joints that were too porous would allow the entry of ground water (infiltration) in times of heavy rainfall and flooding, and would mean handling larger volumes of fluid at the receiving end which would be costly. In addition, because the waste was good fertilizer, tree roots would find their way through such leaks following back on the track of the leaking "fertilizer" and would expand and develop more roots inside the pipe, eventually blocking the flow of the sewage and forcing operators to open and clean out the line–an expensive proceeding.

Thus at about the turn of the century engineers who designed waste handling sewers agreed on an "allowable leakage" which was generally accepted as a standard throughout North America. This was 200 U.S. gallons per inch of (internal) diameter per mile of pipe per day. This appears to have been satisfactory for sanitary sewage during this period and as industrial wastes were at this time generally (there were exceptions) considered rather innocuous, it was usual (with the same few exceptions) to handle them in the same manner. Pipelines were, therefore, designed to this standard.

In the early 1950s it became apparent that serious contamination from liquid industrial wastes was becoming a problem. Fish no longer were found in many streams and rivers. Greasy, oily slicks covered the surface of some ponds and waterways where children used to swim. In many locations, it was impossible to use water from the customary sources for household purposes. Therefore, the allowable leakage standard was seen as not acceptable for industrial wastes, and in many areas it was cut by 75% to 50 gallons. This still was not good enough, and in recent years it has been further cut so that, in many cases, any visual leakage from a 5 pound test load, was unacceptable. Sanitary sewage is still allowed a bit more latitude, but the design engineer should remember that since small amounts of industrial wastes often find their way into sanitary lines serious damage may occur before it is found, if care in assembly and inspection is not taken.

Obviously oakum packing with a hot asphalt pitch or tar backing cannot be used for present day industrial wastes, nor can one expect to get fully tight joints in this manner even for gravity sanitary lines, whether they are backed with a hot poured sealant or packed with portland cement. In present day design, joints in vitrified clay pipe are most often specified in the manner shown in Sketch 1.

In *Water and Sewage Works* magazine, December, 1975 (Vol. 122, No. 12, pp 64-67) the writer discussed the methods of making joints in vitrified clay pipe, the materials that are or can be used to make these joints, and the problems inherent in making the joints liquid tight. Clay pipe in this hemisphere is generally made to ASTM C-700. In the manufacture and firing of clay pipe a certain amount of distortion must be anticipated. From the variations in dimensions that can exist in pipe made to meet this standard it can be seen that the joint sealant must be able to hold the pipe together and function satisfactorily in a pipeline assembled in a dead straight line with considerable dimensional differ-


CLAY PIPE
CONTINUOUS CONCRETE CRADLE
SADDLES
3 RINGS OF OVERSIZE CERAMIC WICKING SATURATED WITH RESIN MORTAR PACKED IN TIGHTLY.
APPROPRIATE MORTAR
BACKING CEMENT 1" MINIMUM DEPTH OR AS SPECIFIED
JOINT MUST BE FULL
NOTE: BEFORE ASSEMBLING PIPE, CLEAN AND SAND LIGHTLY THE SHOULDER OF BELL AND END OF SPIGOT. APPLY MORTAR TO SPIGOT END AND TO SHOULDER OF BELL. THEN SEAT AND CENTER SPIGOT INTO BELL. TIE DOWN PIPE TIGHTLY BEFORE CAULKING JOINT.
SMALL DIAMETER PIPE IS FREQUENTLY ENCASED IN CONCRETE. MEDIUM DIAMETERS MAY BE ENCASED UP TO SPRING LINE.
NOT DRAWN TO SCALE.

Sketch 1: Acid-resistant joints for terra-cotta pipe.

ences at each of the available sizes shown in Table 2 in the subject standard. Table 2 of the standard in the year of publication of the article supplied full figures of the variations of acceptable pipe including the barrel thickness from which the outside possible range of annular space at the opposite sides of the joint could be determined. In 1975 when the article was written this showed the possible variation in a 4 in. joint to be ½ in. and variations increasing with internal diameter until at 42 in. the possible variation is 3¾ in. However, in the latest revision (1978) of this standard still in use at the time of this writing, the table has unfortunately been much abbreviated, omitting tolerances of barrel thickness, and outside dimensions of the barrel, so that with the current specification it is not possible to determine *exactly* what the possible variation in the annular space is. Accordingly, whether there is or is not an intention on the part of the manufacturers to adhere to the same dimensional tolerances is not known. For the benefit of the reader, and the better to illustrate the problem this omission creates, both sets of tables are here reproduced; first the table from the issue of 1971, second the current issue (the edition of 1978).

Refer back to Sketch 1. Before assembling the pipe, the outside of the spigot end and the inside of the mating bell, including the end of the spigot and shoulder of the bell, should be sanded to remove the hard burned surfaces. The end of the spigot and the shoulder of the bell are then buttered with a stiff mix of resin mortar, usually a furan. The spigot is then seated in the bell and shoved home against the shoulder of the bell.

Next a long enough section of random ceramic fiber (or very lightly twisted roving) thicker around than the largest section of the annular space is wide, into which has been worked a *slightly* thinner mix of the same resin mortar, is caulked into the annular space to form a ring around the shaft of the pipe, with ends overlapping at least 2 in., and, with a caulking tool, driven home tightly against the shoulder of the bell, so that the ring is *tightly* in contact with the interior of the bell, all the way around the pipe. Next, a second ring of ceramic fiber saturated with the resin mortar and thicker than the width of the widest section of the annular space, is driven in on top of the first, with the lap of the ends at the *opposite* side of the bell. A third ring follows the first two in the same manner.

TABLE 2 Dimensions of Clay Pipe

Nominal Size, in.[a,b]	Laying Length[c]		Difference in Length of Two Opposite Sides, max, in. (mm)	Outside Diameter of Barrel, in. (mm)[d,e]		Inside Diameter of Socket at ½ in. (13 mm) Above Base, min, in. (mm)[f,g]
	min, ft (m)	Limit of Minus Variation, in./ft (mm/m)		min	max	
4	2 (0.61)	¼ (20)	5/16 (8)	4 7/8 (124)	5 1/8 (130)	5 3/4 (146)
6	2 (0.61)	¼ (20)	3/8 (9)	7 1/16 (179)	7 7/16 (189)	8 3/16 (208)
8	2 (0.61)	¼ (20)	7/16 (11)	9 1/4 (235)	9 3/4 (248)	10 1/2 (267)
10	2 (0.61)	¼ (20)	7/16 (11)	11 1/2 (292)	12 (305)	12 3/4 (324)
12	2 (0.61)	¼ (20)	7/16 (11)	13 3/4 (349)	14 5/16 (364)	15 1/8 (384)
15	3 (0.91)	¼ (20)	½ (13)	17 3/16 (437)	17 13/16 (452)	18 3/8 (473)
18	3 (0.91)	¼ (20)	½ (13)	20 5/8 (524)	21 7/16 (545)	22 1/4 (565)
21	3 (0.91)	¼ (20)	9/16 (14)	24 1/8 (613)	25 (635)	25 7/8 (657)
24	3 (0.91)	⅜ (30)	9/16 (14)	27 1/2 (699)	28 1/2 (724)	29 3/8 (746)
27	3 (0.91)	⅜ (30)	⅝ (16)	31 (787)	32 1/8 (816)	33 (838)
30	3 (0.91)	⅜ (30)	⅝ (16)	34 3/8 (873)	35 5/8 (905)	36 1/2 (927)
33	3 (0.91)	⅜ (30)	⅝ (16)	37 5/8 (956)	38 13/16 (989)	39 7/8 (1013)
36	3 (0.91)	⅜ (30)	11/16 (17)	40 3/4 (1035)	42 1/4 (1073)	43 1/4 (1099)
39	5 (1.52)	¼ (20)	¾ (19)	45 5/8 (1152)	47 1/4 (1200)	48 1/2 (1232)
42	5 (1.52)	⅜ (30)	⅞ (23)	48 1/2 (1232)	51 (1295)	52 1/2 (1333)

Nominal Size, in.[a,b]	Depth of Socket[f,g]				Thickness of Barrel[d,h]						Thickness of Socket at ½ in. (13 mm) from Outer End[g]			
	nominal, in. (mm)		min, in. (mm)		Extra Strength				Standard Strength				nominal, in. (mm)		min, in. (mm)	
					nominal, in. (mm)		min, in. (mm)		nominal, in. (mm)		min, in. (mm)					
4	1 3/4	(44)	1 1/2	(38)	5/8	(16)	9/16	(14)	1/2	(13)	7/16	(11)	7/16	(11)	3/8	(9)
6	2 1/4	(57)	2	(51)	11/16	(17)	9/16	(14)	5/8	(16)	9/16	(14)	1/2	(13)	7/16	(11)
8	2 1/2	(64)	2 1/4	(57)	7/8	(22)	3/4	(19)	3/4	(19)	11/16	(17)	9/16	(14)	1/2	(13)
10	2 5/8	(67)	2 3/8	(60)	1	(25)	7/8	(22)	7/8	(22)	13/16	(21)	5/8	(16)	9/16	(14)
12	2 3/4	(70)	2 1/2	(64)	1 1/16	(30)	1 1/16	(27)	1	(25)	15/16	(24)	3/4	(19)	11/16	(17)
15	2 7/8	(73)	2 5/8	(67)	1 1/2	(38)	1 3/8	(35)	1 1/4	(31)	1 1/8	(29)	15/16	(24)	7/8	(22)
18	3	(76)	2 3/4	(70)	1 7/8	(48)	1 3/4	(44)	1 1/2	(38)	1 3/8	(35)	1 1/8	(29)	1 1/16	(27)
21	3 1/4	(83)	3	(76)	2 1/4	(57)	2	(51)	1 3/4	(44)	1 5/8	(41)	1 5/16	(33)	1 3/16	(30)
24	3 3/8	(86)	3 1/8	(79)	2 1/2	(64)	2 1/4	(57)	2	(51)	1 7/8	(48)	1 1/2	(38)	1 3/8	(35)
27	3 1/2	(89)	3 1/4	(83)	2 3/4	(70)	2 1/2	(64)	2 1/4	(57)	2 1/8	(54)	1 11/16	(43)	1 9/16	(40)
30	3 5/8	(92)	3 3/8	(86)	3	(76)	2 3/4	(70)	2 1/2	(64)	2 3/8	(60)	1 7/8	(48)	1 3/4	(44)
33	3 3/4	(95)	3 1/2	(89)	3 1/4	(83)	3	(76)	2 5/8	(67)	2 1/2	(64)	2	(51)	1 3/4	(44)
36	4	(102)	3 3/4	(95)	3 1/2	(89)	3 1/4	(83)	2 3/4	(70)	2 5/8	(67)	2 1/16	(52)	1 7/8	(48)
39	4 1/8	(105)	3 7/8	(98)	3 3/4	(95)	3 3/8	(86)	...	...	...	...	2 3/4	(70)	2 5/8	(67)
42	4 1/8	(105)	3 7/8	(98)	4	(102)	3 1/2	(89)	...	...	...	...	2 3/4	(70)	2 5/8	(67)

[a] Specifiers should be aware that all pipe sizes are not universally available.

[b] Sizes on perforated pipe apply only to nominal sizes 4 through 24 in.

[c] There shall be no maximum length. Shorter lengths may be used for closures and specials.

[d] Pipe having the nominal thickness of barrel shown in Table 2 may have smaller inside diameter than the nominal sizes.

[e] The outside diameter of the barrel may be greater than the maximum figures stated in Table 2, provided the other dimensions are varied accordingly within the specification tolerances.

[f] The minimums for inside diameter of socket and depth of socket may be waived where such dimensions are conducive to the proper application of the joint.

[g] Plain-end pipe shall conform to the dimensions in Table 2, except those dimensions pertaining to sockets.

[h] The requirement for minimum barrel thickness may be waived when satisfactory evidence is presented that the pipe can meet the required crushing strength and all other requirements of this specification.

(continued)

C 700

TABLE 2A Dimensions of Vitrified Clay Pipe (SI Units)

Nominal Size, mm[A]	Laying Length Limit of Minus Variation, mm/m	Difference in Length of Two Opposite Sides max, mm	Limit of Minus Variations from Nominal Size in Average Inside Diameter, mm
75	20	8	4
100	20	8	4
150	20	9	4
200	20	11	5
250	20	11	6
300	20	11	7
375	20	13	9
450	20	13	11
525	20	14	13
600	30	14	15
675	30	16	17
750	30	16	19
825	30	16	21
900	30	17	22
975	30	19	22
1050	30	23	22

[A] Specifiers should be aware that all pipe sizes are not universally available.

After the third ring is caulked into the space, there should be, if the rings are placed as described, a ¾ to 1 in. space left in the depth of the bell of a 4 in. line up to a 1½ in. space or larger in the 42 in. pipe. This space is now filled with a mortar caulk, either of hot poured sulfur mortar or a low shrinkage resin mortar, hand packed into place. The liquidtight seal cannot be accomplished with the mortar between spigot end and the shoulder of the bell. A look at the large space that can exist between one side of the spigot and the shoulder of the bell, if the pipe is laid in a straight line, will tell you that you can never hope to seal the joint at this point. Neither can it be accomplished with the caulk at the end of bell. This mortar can shrink on curing and leave voids through which liquid can pass. The seal relies totally on the quality of the workmanship in installing the three rings. The caulk at the end of the bell acts merely as *an anchor to hold those rings in place*. The mortar applied first between spigot end and bell shoulder functions only to *reduce* fluid approach to the rings, and to fill or smooth the cavity at the inner surface of the pipe. Therefore, the rings must be composed of soft enough, deformable enough material to caulk tightly into the annular space. A quick look at the tables reproduced above will show the reader at once that a hard material such as the "braided rope" specified in the past by many manufacturers can never be caulked into the annular space tightly enough to accomplish the purpose. A look at the cure shrinkage shown for sulfur mortars and for resin mortars (see Section V) also makes it clear that the final caulk at the end of the pipe cannot be depended upon to seal the pipe.

So that the reader will have adequate information to prepare proper specifications for the pipe he is to purchase, I quote from my cited article, to provide those exceptions he should take, beyond the minima given in the standard.

The clay pipe used for conveyance of industrial wastes should be unglazed, extra strength pipe, conforming to ASTM specification C 700-71.

From this specification it will be evident that the pipe itself, if it conforms to the specification, will be adequate in strength for gravity and low pressure waste handling, and that it is now available in sizes from 4 to 42 in. internal diameter. There are, however, three limitations that the buyer, if he plans to use the pipe in nonleaking industrial sewers, must bear in mind. In this specification:

(1) Section 9, Fractures and Cracks, permits the manufacturer to furnish pipe that has no cracks in the barrel, but does have a single crack in the spigot end not exceeding 75 percent of the depth of the socket, or a single fracture in the socket end not exceeding three inches around the circumference nor two inches lengthwise. Chips and fractures on the interior shall not exceed two inches in length, one inch in width, and/or a depth of 1/4 of the thickness of the barrel. Yet no cracks, fractures, or chips whatsoever are acceptable if a liquidtight line is to be attained.

(2) Section 4, Physical and Chemical Requirements, subsection 4.2 Absorption and 4.3 Hydrostatic Pressure Test. The effect of these two subsections is to permit a water absorption of the clay pipe as high as eight percent and a hydrostatic test of ten psi that accepts beads of "sweat" on the outside of the pipe, but no running liquid to appear under a test duration ranging from 7 minutes for 4 to 10 inch pipe, 21 minutes for 36 to 42 inch pipe. An absorption this high will *not* provide a liquidtight line, and the pressure test should be maintained for at least three days (72 hours) regardless of the diameter. Most first quality pipe will be well below the above maximum absorption and will easily meet a three day pressure test.

(3) Section 10, Finish of Ends, states "the ends of the pipe shall be square with their longitudinal axes within the tolerances provided in Table 2." This same section also defines the scoring on the inner surface of the bell and the outer surface of the spigot and permits the elimination of scoring "when it is conducive to the proper application of the joint to be used." The engineer should be certain that the scoring is provided on pipe that he buys.

Originally the fiber specified for the three ring seal was African blue asbestos, as the best chemically resistant material for this work. Today asbestos, whether blue or white, is rarely available, so that current specifications call only for a soft random ceramic fiber made from the same clay sources as various "acid brick" such as Fibrefrax® or KaoWool®. This may be a three strand, *lightly* twisted mass of material, provided that the three strands are separated and used independently. The material of choice is the loose fiber mass (usually called "roving" by textile manufacturers or "sliver" by asbestos manufacturers) which may be lightly twisted to retain integrity, but is soft enough to saturate

fully with the soft wet resin mortar mix and to caulk tightly into the joint to provide a plug in tight contact with all sides.

The selection of resin mortar to use to fill the contact area between shoulder of bell and end of spigot, and to saturate the ceramic caulk depends on the chemical exposure anticipated for the sewer. The usual material is a furan resin. However, if strongly oxidizing material is likely to be present, the designer should consider using a vinyl ester or polyester resin. Strong solvents are in most cases best handled by phenol formaldehyde or furan resins, and if oxidants and solvents are both to be encountered the choice would probably go to the former. In all events the designer should discuss the anticipated chemical content of the stream with the resin manufacturer *before* making his decision.

Strong alkalies will damage the pipe. If the alkali content (pH) is expected to be high enough to destroy a vinyl ester mortar, it will probably be too high for the pipe itself. If this possibility arises the matter should be discussed with the pipe manufacturer or the National Clay Pipe Institute. Consider also the temperature at which liquid streams may enter the pipe. The cited standard limits service conditions to 140°F or lower. If very hot liquids are to enter the system, this too should be discussed with the pipe manufacturer.

Finally, the selection of the caulk at the end of the bell, which will hold in the three rings must be made. Here hot poured sulfur mortar plasticized with 1.2% Thiokol® is the most commonly employed material. This, as previously noted, cannot be expected to in itself yield a liquidtight joint, but it *will* provide a sound anchor for the rings. It has three specific advantages over most other materials. (1) Being poured hot, joints can be finished with it in an unheated trench in freezing or even sub-zero weather. (2) If the rings were caulked in at a temperature below the lowest cure temperature of the resin, but not as low as freezing, the heat of the sulfur pour will provide sufficient heat to finish the cure of the resin material in the three rings. (3) A *poured* joint is a completely *full* joint, providing a "pouring gate" is employed. Pouring of the joint is done slowly, but continuously and steadily, filling the gate so that cure shrinkage takes place in the gate and not in the top of the joint, to assure that the joint is completely filled. If the joint is hand caulked, common labor being what it is, only by monitoring and careful inspection can it be certain that the bottom of the joint is completely filled. The only disadvantage is the high degree of shrinkage of sulfur mortars (>4%) on hardening from liquid to solid.

If it is vital for the caulk to act as a safety seal behind the three rings, then the sulfur must be replaced by the strongest and lowest shrinkage resin mortar available–an epoxy (<0.1% shrinkage). If this is to be used, great care in monitoring and inspecting the installation will be required to be certain that the joint is completely full–especially at the *underside* which cannot be seen from the top or from the side of the pipe. Although not yet noted, it may well be that a pourable epoxy grout can be developed which can accomplish this purpose and solve this problem.

A common joint design for clay pipe, one which the pipe manufacturer will probably try to sell, is a "pressure joint." For this kind of joint an elastomeric or flexible collar is set into, and usually cemented to, the inside of the bell. The inside dimension of the collar is smaller than the outside dimension of the spigot, so when the spigot is seated in the bell the collar squeezes tightly against

the shaft of the pipe, in theory making a tight joint. The collar is often made of neoprene or PVC, although there are other, usually synthetic, materials that may be employed. This type of joint is flexible and allows some independent movement of the two pipes.

There are two limitations to this kind of "pressure joint." (1) As pressures increase on the inside of the pipe, and even in some cases merely the weight of the liquid stream, the contained liquid can squeeze past the collar along the shaft of the pipe and the joint will leak. (2) Many of the waste streams contain solvents or other chemicals that can and will attack these collars, causing them to swell, or to disintegrate, or which can destroy the material cementing them to the inside of the bell, resulting in the loss or popping out of the seal and complete failure of the joint. For these reasons "pressure joints" although often employed in sanitary lines should not be used for industrial wastes or for sanitary lines which may receive streams of industrial wastes.

SUPPORT AND BACKFILL

Chemically resistant masonry joints in clay pipe are rigid. Ground movement, such as settlement, can therefore break the pipe. For this reason it is important that *all* industrial waste lines be laid with continuous support. No matter what opinion others may have of the stability of the soil in the area where the pipe is to be laid, this writer has never seen any trench excavation, no matter how well prepared, that did not require adjustment to attain the suitable smooth surface and slope *after* the trenching operation had been completed. These adjustments require fill in some spots and further surface removal in others. In addition bell excavations are required to provide working room to make the joints. After the line is in service, heavy rains, flooding and even percolation of groundwater can cause soil movement above and around the pipe, and eventually, without uniform support, movement will take place that breaks the pipe.

The only way to insure long life and satisfactory operations of the line is to provide continuous support by pouring a continuous concrete pad a few inches wider than the outside diameter of the bell, the full length of the trench. In addition saddles should be provided under the shaft of the pipe at the bell end so that the saddle, besides acting as support for the pipe, holds it steady during the caulking. In lengths beyond six feet, additional intermediate saddles should be added to distribute the load. One of the major chemical companies used to require that all clay pipe of 12 in. diameter or less be fully concrete encased and all clay pipe of larger diameter be given continuous full support up to the spring line. Suffice it to say that while these specifications were followed this company never lost an industrial sewer.

All spoil from the trench that is to be used in backfill, to the depth of 1 ft. above the pipe should be screened to remove all rock or stone greater than ½ in. in diameter. Backfill should be carefully tamped at frequent intervals to be sure that it is solidly placed around and under the pipe between saddles and tightly between the walls of the ditch, and such fill and tamping done carefully and after every few inches of backfill until one foot above the pipe line, at which time the unscreened spoil may be used, and as needed to fill the space, stone

screened out earlier may be added. Compacting should be done carefully and continuously as the fill is added. Failure to keep stone away from the shaft or bell of the pipe will almost certainly result in cracked pipe.

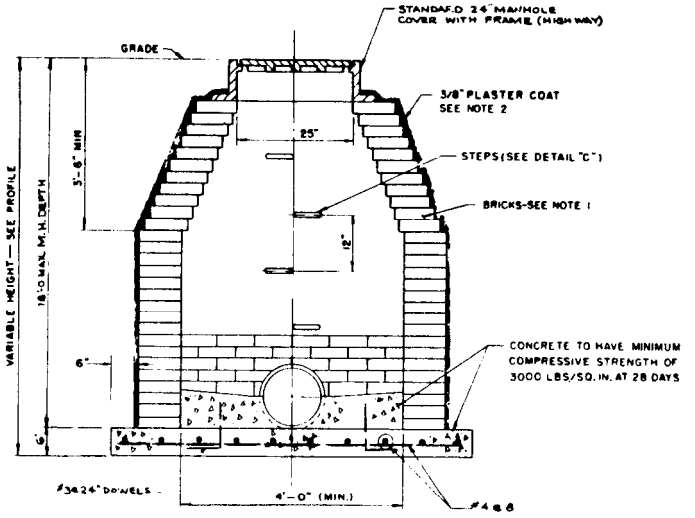
In most specifications, testing of joints is required after backfill and tamping is complete. The designer should understand, however, that if a leak shows up on testing, it will be necessary to uncover the line to make repairs. This writer has found it far better to test before backfill, make repairs if necessary, then backfill, tamp and test again. In the long run it is generally far less expensive to test twice, especially considering the quality of the labor used to caulk the joints.

MANHOLES

The greatest individual source of trouble with industrial waste sewers has been maldesign of manholes. Through the first three decades of the twentieth century engineers used the same specification for manholes, whether they were to be used in sanitary or industrial sewage. They were most often built entirely out of common red shale brick laid in portland cement mortar, usually with concrete bottoms, into which the ends of the clay pipe were set. Often the clay pipe line was laid first, concrete poured around it up to the spring line or the midsection of the pipe then the brick laid in a circle over the section where the manhole was to be. After all the brick was laid, the workmen would go back onto the manhole with hammer and chisel and break out the exposed top of the clay pipe. When it became apparent that most chemicals in the waste lines, especially those with low pH, would penetrate through the brick and concrete and channel back along the clay pipe where it was in contact with the poured concrete, they tried to seal or line these structures with coatings of hot asphalt and occasionally with acid brick over the coating. It is a waste of time and money to try to build one from block or brick. In doing so they violated three of the principles of chemically resistant masonry: (1) Chemically resistant masonry is no good in tension or shear. It must be supported. The common brick/portland cement outer structure is unreinforced and has no strength in tension or shear either, so it cannot give support to the lining. As the manhole fills with liquid, or the filled ground outside it moves, the brick manhole itself must crack so any lining inside it will also crack. (2) The masonry is not liquidtight, and therefore, a liquidtight membrane is a necessity over the supporting structure prior to putting in the "acid brick" lining. The coating or asphalt applied is called a "sealer," but it is rarely thick enough or sufficiently uniform to be liquidtight. (3) In addition, there is no way to seal the joint between the edges of the clay pipe and the concrete or the brick walls, so even if the membrane is tight and the contained liquids cannot get back to the substrate, it can bypass the membrane at those juncture points which cannot even be protected properly with the brick lining.

The only satisfactory manhole design is one that is monolithic. It is a waste of time and money to try to build one from block or brick. A monolithic manhole should be formed and cast, properly reinforced, of concrete in which all pours are wet to wet or the cold seams protected by a continuous water-stop and a concrete adhesive employed on each wet to dry pour. Such design requires that the bottom slab be an integral part of the structure. The next alternative is to

construct the manhole of preformed sections, put together with tongue and groove type joints and employing an epoxy mortar continuously and generously in all joints. A prefabricated concrete manhole may be used, providing there are no cold seams discoverable in the structure. Regardless of type, the manhole should be tested liquidtight before being accepted for lining. (See the instructions for this test in Section X on *Design*.) If the designer decides on the use of FRP pipe or other plastic, a standard on a prefabricated FRP manhole, made from polyester resin is available. (See ASTM D 3753-79).



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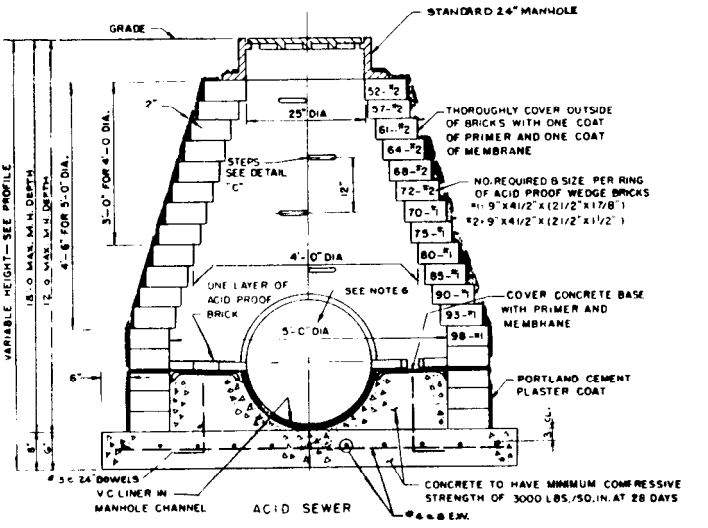
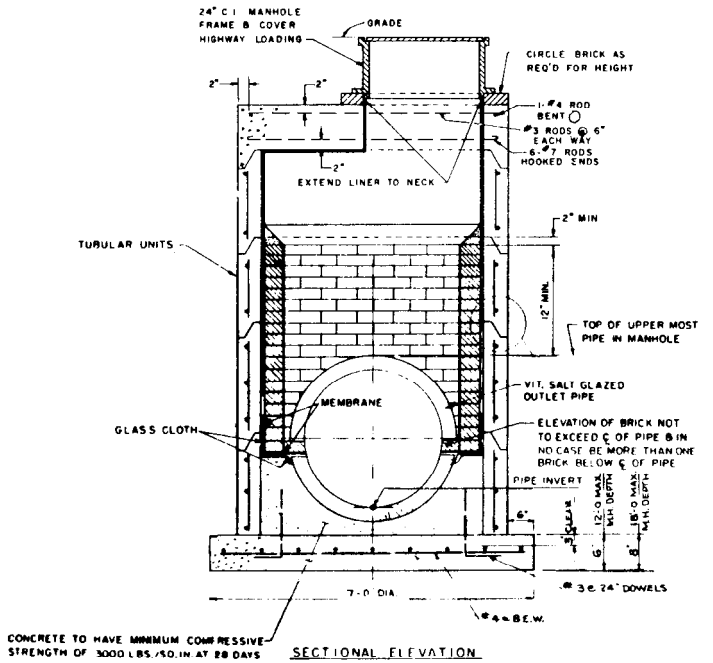


B—Typical redesign for industrial wastes.

(continued)


24" C.I. MANHOLE FRAME & COVER HIGHWAY LOADING
GRADE
CIRCLE BRICK AS REQ'D FOR HEIGHT
2"
2"
1-#4 ROD BENT
#3 RODS @ 6" EACH WAY
6-#7 RODS HOOKED ENDS
2" EXTEND LINER TO NECK
2" MIN
TUBULAR UNITS
12" MIN.
TOP OF UPPER MOST PIPE IN MANHOLE
VIT. SALT GLAZED OUTLET PIPE
MEMBRANE
GLASS CLOTH
ELEVATION OF BRICK NOT TO EXCEED ℄ OF PIPE & IN NO CASE BE MORE THAN ONE BRICK BELOW ℄ OF PIPE
PIPE INVERT
12'-0 MAX M.H. DEPTH
18'-0 MAX M.H. DEPTH
6"
3"
6"
8"
7'-0 DIA.
#3 @ 24" DOWELS
#4 @ B.E.W.
CONCRETE TO HAVE MINIMUM COMPRESSIVE STRENGTH OF 3000 LBS./SQ.IN. AT 28 DAYS
SECTIONAL ELEVATION

C–Modification supplies support.

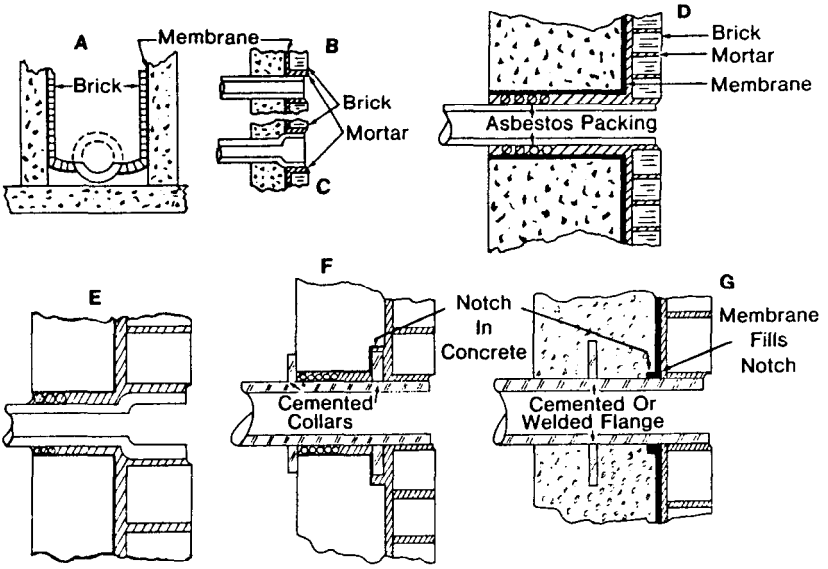
Note that *neither* **A** nor **B** provides either the continuous external support required to keep the brickwork tight. **C** supplies support but none have an interior continuous lining of a liquidtight membrane.

Sketch 2: From *Chemically Resistant Masonry,* 2nd Ed., Marcel Dekker (1982).

Inlets and outlets must be so designed that all joints between the manhole body and the fitting be tightly sealed with a liquidtight seal so that the membrane surface is continuous and completely uninterrupted. In addition, the fitting should be totally immobilized so that any movement of the connecting line, whether thrust, pull or sideways, will not disrupt the connection with the body of the manhole or rupture the membrane. Note the details in Sketch 3 which show both how they should not be designed and what designs are best.

TRENCHES

Liquid waste transmission above ground is often handled by gutters and trenches which pick up pollutants and chemicals dripping or spilling on floors and around equipment. The section on design covers the principles of design and construction so they will not be repeated here. However, space must be given to a design frequently suggested, especially by those unfamiliar with the limitations of chemically resistant masonry, which can cause difficulty for the designer and owner if the wastes conveyed in it are to be kept out of the substrate and out of the soil below it.

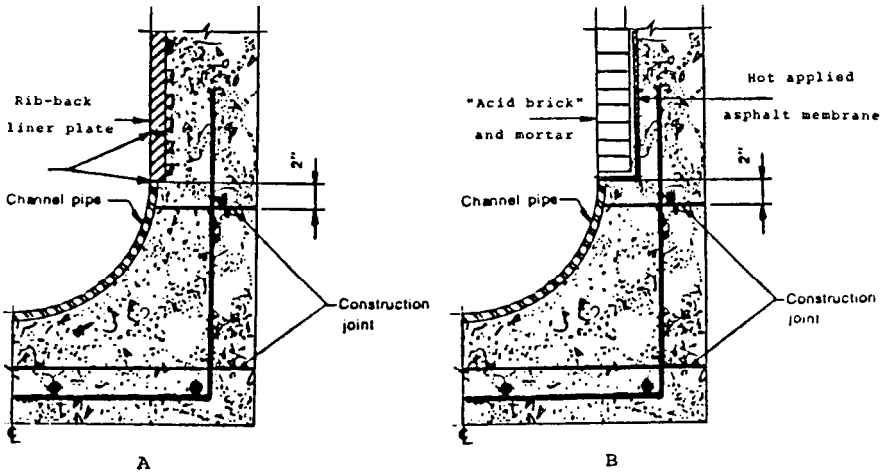


A–With concrete outer shell, we now have support for the brick, but note that the membrane is discontinuous at the bottom where it terminates at pipe edge.
B–This is a typical inlet design, with the entry pipe simply embedded in the wall, membrane brought to pipe edge and brick laid around the intruded pipe. Ground movement or expansion/contraction of the pipe can push or pull the pipe through the cavity in the concrete and cause the joint and membrane to be disrupted, and contained liquid to get back to the concrete.
C–A slight improvement over **B** in that the pipe cannot be pulled out, but it can be pushed in.
D–This is a much improved design. The membrane is carried through a cavity in the concrete to the outside. The pipe is carried through the cavity, inside the membrane, centered by seal rings of caulking, installed in the same manner as the seal rings in the pipe joints, and the balance of the annular space packed full of furan resin mortar. The brick is laid up to and bonded to the intruded pipe with the same furan resin. The only difficulty with this design is that the pipe can still be pushed in or pulled out, so disrupting the joint. However, if this happens, the contained fluid can only leak along the shaft to the outside, without getting through the membrane to attack the concrete manhole.
E–This design prevents "pull out," but not "push in."
F–Here the pipe is successfully anchored against movement in or out, and the membrane is still continuous to the outside. This is the best design.
G–If the pipe line is plastic or steel, this design, although less perfect than **F**, may be used. It holds the pipe rigidly in place to prevent movement but relies for membrane tightness on the seal at the internal notch so that any leakage at that point can enter the concrete along the shaft.

Sketch 3: From *Water & Sewage Works*, Vol. 127, No. 2, pp 51.

The normal design of a trench is rectangular, with brick lining on the bottom and the two sides. In order to lay brick in the bottom of a narrow trench, especially if it is deep, the mason must kneel along side of it and reach into it. If the concrete forms are not set exactly on multiples of the brick size,

there will also be a lot of cutting of the brick required to fit the bottom. Years ago, someone came up with what he thought would be a great way to save these labor costs by casting "half round" pipe (also called "channel pipe") manufactured to C700-82a, into the concrete to form the bottom of the trench, and to set ceramic "liner plates" inside the forms for the walls. Rubber separators, ¼ in. wide, would be set between the plates. When the forms were stripped, all that would have to be done to finish the trench would be to remove the rubber separators and point all the joints with a resin mortar appropriate to the chemical exposure. See Sketch 4, Drawing A.



Sketch 4

Note that in Sketch 4, Drawing A, there is no membrane at all. If any of the joints leak, the chemical waste will get into the concrete behind the tile and soon the layer of concrete bonding the tile to the wall will be attacked and the tile will fall into the trench. Note also, that vitrified clay liner plates are manufactured to conform to ASTM Standard C479-82 which allows an absorption of 6%. According to this standard, although an acid-soluble limit is set at 0.25%, no specific test is specified to be run, and further, the standard says that this (undescribed) test is only to be run if specified. In addition, some surface defects (including small cracks) are permissible. It must be evident, therefore, that even if the contained liquids fail to penetrate through the joints, they will certainly, in not too long a time, get through the bodies of the tile. Without a membrane, one can expect attack on the substrate. So we next find a modification of this design, Drawing B, where a membrane is applied on the walls, and "acid" brick laid over the membrane and bonded to the half-round pipe in the trench bottom.

Just as in the case of the manholes, we are dealing here with a discontinuous interrupted membrane, and there will be leaks in the bottom just as there were in the manholes of the old design, but through the channel pipe (ASTM C700) and at the termination of the membrane against the edge of the channel pipe.

To prevent such leaks in the bottom, the membrane must be continuous down the sides and *under* the channel pipe. Thus the concrete may be formed to accept the channel pipe, including depressions at the correct locations to accept the bells of the channel pipe, then the membrane applied, and finally the channel pipe installed, making the joints between sections as we fit the sections. By the time all this is done, it is likely that there will have been consumed as much, or even more, labor cost (including some expensive concrete work) than if brick had been laid.

Where half-round pipe is merely set in the floor to create a gutter, the floor is poured around it. Anyone who designs a gutter this way should bear in mind the following: (1) If the half-round pipe is set in the forms as part of the laying of the floor, the pressure of concrete poured next to it and under it will "float" out the pipe unless it is heavily braced. (2) The acid-resistant joints will have to be made before the concrete is poured under it to prevent the intrusion of portland cement concrete into the pipe joints. But these joints are hard and brittle, so if the pour causes any movement in the half-round pipe, the joints will be broken. (3) Trenches and gutters are designed to run only at half-depth, so as to accommodate surges without overflowing. At half-depth, only one-third of the capacity of half-round pipe will be provided because it will be half as deep as it is wide–so the gutter will have to be wider for the same capacity as if designed rectangular–using a lot of floor space for a minimum capacity. (4) If liquids run rapidly over the floor toward the gutter–as from a spill, when they splash into the gutter–they will cross the top of the gutter and strike the other side. In a rectangular cross section gutter, this rapidly moving liquid will splash across to the other side–which is vertical. From the opposite side, the liquid will splash back and down into the trench.

In the case of half-round pipe, the opposite side of the gutter is not vertical, but sloped down and back toward the source of the liquid, so instead of bounding *into* the gutter, the waste will be reflected upward and out of the gutter, onto the floor on the other side. Therefore, for all these reasons, even with the amount of brick cutting that may be required, this design is not recommended.

HOLDING, "EQUALIZING," OR NEUTRALIZING TANKS

The usual construction material for tanks to contain or process liquid is concrete, with suitable linings. Concrete is the material of choice if the vessels are set on or partly in the ground. (See the section on *Design* for information on this type of construction.) Alternates are plastic or rubber-lined steel, FRP, or even wood. The paper on wood in the *Supporting Structures* section provides some design data on this material, and chemical resistance data for wood tanks is supplied in the two Technical Bulletins of the National Wood Tank Institute cited in the bibliography of that section. If above ground storage tanks or process tanks or process equipment is planned, the designer should be sure that it is elevated above ground to provide for ventilation under the bottom, external cleaning and inspection, so that if leaks develop, they may be discovered quickly and repaired before extensive damage can occur.

SCRUBBERS AND ANCILLARY EQUIPMENT

Many scrubber designs make effective use of chemically resistant masonry, especially in the contact area between the scrubbed gases and the scrubbing liquid. The receiver may also be brick-lined as may trenches carrying the waste liquid. If bleeding of the waste and recirculation are planned, additional equipment may also be considered for lining. The *Design* section covers the recommended procedures to be followed.

INSPECTION AND REPAIRS OF MANHOLES AND CLAY PIPE

During installation of clay pipe and manholes, careful inspection and rigid compliance with specifications is essential. It should be borne in mind that after installation, it is impossible to inspect the workmanship from the outside, and internal inspection is possible only for the exposed surface. There is no way that an inspector can verify that either the membrane or the substrate of the manhole comply with specifications, that holidays do not exist, and that membrane thicknesses are as specified. The inspector should check all work carefully as it progresses, including all membranes prior to brick installation, and all joints in pipe as they are caulked.

Water tests on pipe should be made, both before and after backfill. If backfilling is done *before* testing, there is no way to identify which joint is leaking, and the entire line will probably have to be uncovered—a most difficult task when one remembers that the most common point of leakage is the bottom of the joint. On the other hand, if no test is run after backfill, the owner may not find out for some time that the pipe and/or the joints were disturbed during backfill and tamping, and that the line now leaks. Such damage is often noted when stone is included in the backfill, and where heavy equipment is used in compacting the soil.

Where interruptions in the membrane lining in the manholes occur, waste chemicals get back into the concrete manhole body and damage or destroy it over a period of time, resulting eventually in the collapse of the manhole. It is usually a waste of effort to try to repair a manhole that leaks because by the time the leak is discovered, the waste chemicals have usually saturated the concrete, and damage is too widespread. It is better to abandon the manhole completely.

During the following repair, the temperature of the area and all components must be kept to a minimum 60°F.

The flow through the system is stopped off upstream at the next manhole or point of entry, and the damaged manhole is bypassed, bringing the wastes back into the line downstream. The old manhole construction is completely excavated, removing all contaminated soil and exposing the pipe ends. Plugs are put in the pipe ends to prevent the intrusion of rubbish, and the outsides of the pipes are cleaned and sanded. Inner and outer concrete forms are built around the pipe with the ends passing 3 to 4 in. through the inner form, the inner space and bottom is poured with new high-early concrete. If pressed for time, the new manhole body may be completely poured with epoxy grout. Although this is quite costly, it will cure in 24 hours, and if properly done may not require a membrane and brick lining, depending on the chemical exposure.

If joints in the pipe leak badly, it is a waste of time to try to fix the leaks by caulking or with the use of sealers, or with a so-called "diaper joint" wrapped around the joint and filled with hot sulfur or asphalt. Repairs from the outside will assist in stopping *infiltration,* but the seepage of *exfiltration* will eventually start again, pushing off any kind of seal applied on the outside. The only way to stop a leaking joint is to cut it out and replace it. If all, or most, of the line leaks, the pipe should be replaced. 90% of the time, doing the job over again is less costly, and faster, than trying to save what was done wrong to start with. There is now, however, a *possible* way to make a repair internally, and this will be covered later.

Armoring

If the shaft of the pipe, or even a joint, is cracked or otherwise damaged, and the line is leaking through the crack, the line can often be saved, or at least kept in service for a considerable length of time by "armoring" it with glass fabric and furan mortar.

This is done in the following manner. During all the following steps, the pipe must be kept at 60°F or higher.

(1) Clean the entire exterior of the damaged section around the full circumference and for 4 in. each side of the fracture, and then sand it carefully to remove all the hard burned surface of the pipe.

(2) Measure out three lengths of light, soft, loose weave, glass cloth (as described in Chapter 13), each long enough to go twice around the pipe, and wide enough to cover the entire cleaned area.

(3) Prime the pipe surface with a primer recommended by the manufacturer of the furan resin mortar you plan to use.

(4) Mix the furan resin mortar in a soft mix, using 10 to 15% more resin than in the bricklaying mix (but first check with the manufacturer to obtain his agreement) *and with your hands*, work it into one of the strips of glass cloth until the cloth is completely saturated, and the entire cloth is black.

(5) Starting at one end of the cloth, wrap it tightly and smoothly around the pipe, covering the fractured area completely *twice* with layers of cloth. Apply a C-clamp or an equivalent to hold it in place until it cures. Keep it warm (60°F minimum).

(6) 24 hours later, this bandage should be hard. If it is not, apply heat until it *is* hard.

(7) Remove the C-clamp and repeat steps 5 and 6, but this time wrap the cloth tightly in the opposite direction.

(8) Repeat these steps once more making a third bandage with the third piece of cloth, once more counterwrapped. The shrinkage of each bandage will cause it to tighten up. Counterwinding the bandages prevents upper ones from loosening the one below it, and causes it to pull even tighter.

Although this repair is not a cure-all, properly done, it can last for many years.

Internal Repair

In the last few years, a procedure has been developed for placing a seal on the *inside* of a leaking clay pipe line. The procedure is as follows:

(1) A "sock" is manufactured of a soft feltlike fabric heavily impregnated with a fluid resin into which has been mixed a hardening (or curing) agent, the reaction with which is initiated by heat in the 150°F range, but which remains unaffected at ambient temperatures. The outside of the "sock" is completely covered with a urethane coating. The diameter of the "sock" is made identical with that of the pipeline to be repaired and the length the same as the distance between the interiors of the manholes on each end of the section requiring lining.

(2) The "sock" is turned inside-out as it is pulled into and through the pipe, and cold water is pumped into the "sock" to inflate it fully, and to press the resin-soaked felt side against the walls of the pipe.

(3) As soon as the sock is fully inflated, the water in the "sock" is circulated through a heat exchanger bringing the internal temperature up to 180°F, at which temperature the water is held until the resin is fully hardened and cured.

The entire interior of the pipeline should now be covered by a liquidtight lining. The closed end can now be cut off, the two ends sealed into the manhole linings, and the waste line returned to service.

This type of lining was originally designed for the repair of sanitary services, and the first resins used belonged to the terephthalate polyester class. Interest at once centered on repairs to industrial waste lines and in some cases, it was obvious that better chemical resistance was required than that offered by this resin type. Although considerably more expensive, this same general system, but employing epoxy resins, is now also available. Of course, neither type resin is suitable for all waste exposures.

Service experience is still too short for long-term test data, but what has been seen so far appears to be most encouraging.

BIBLIOGRAPHY

1. Sheppard, Walter Lee, Jr., P.E., *Chemically Resistant Masonry*, 2nd Ed., especially pp 86-111, Marcel Dekker, NYC (1982).
2. Haworth, B.C., and Stokely, J.M., A Better Way to Joint Stoneware Pipe, *Chemical Engineering*, Vol. 66, No. 18, p 182 (September 21, 1959).
3. Sheppard, Walter Lee, Jr., P.E., Acid Proof Joints in Terra Cotta Industrial Sewer Lines, *Water & Sewage Works*, Vol. 122, No. 12, pp 64-67 (December 1975).
4. Clyburn, Harry, and Sheppard, Walter Lee, Jr., P.E., Uses of Chemically Resistant Masonry in Lining Air and Water Pollution Control Equipment, *Proceedings of the North American Masonry Conference,* Boulder, Colorado (August 1978).

5. Sheppard, Walter Lee, Jr., P.E., Redesign Controls Manhole Leakage, *Water & Sewage Works*, Vol. 127, No. 2, pp 50-52 (February 1980).
6. Applications of Chemically Resistant Masonry in Liquid Waste Handling, *Materials Performance*, Vol. 20, No. 3, pp 34-39, NACE Annual Meeting, Chicago, Illinois (March 1980).